 DOI: 10.19601/j.cnki.issn1943 - 9903.2018.1.014

# A Comparative Experimental Research on the Traditional Cultivation Technology and Intensive Cultivation Technology of *Olea europaea*

**Zhengwu ZHANG** *

Institute of Olive Research, Longnan Academy of Economic Forest Sciences, Longnan 746000, China

**Abstract** In order to improve the intensive cultivation and management technology of *Olea europaea* in the high density orchard, through an analysis on the 3 a growth, yield and orchard construction cost for different varieties and different densities in Gansu Wudu ordinary *O. europaea* orchard and close *O. europaea* planting orchard, the appropriate conditions, varieties and density for intensive orchard construction were initially selected. The results showed that the tree height growth in the ordinary orchard was 119% of the tree height growth in the high density orchard, while the ground diameter growth in the ordinary orchard was 112% of the ground diameter growth in the high density orchard, but the yield in the ordinary orchard was only 62% of the yield in the high density orchard; of the 8 new varieties introduced from Spain, "Arbequina", "Arbosana" and "Koroneiki" were the appropriate varieties for the intensive orchard construction; the ratio of the ordinary orchard construction cost to the high density orchard construction cost was 1:6.24. Under high water and fertilizer conditions, the ratio of the ordinary orchard yield to the high density orchard yield was 1:4.481. Therefore, in the flat land area, using the appropriate intensive cultivars, and integrating the high-tech achievements and advanced management tools, can increase output per unit area, and greatly save manpower and land costs, to achieve the purpose of high quality, high yield and stable production. In the production practice, it is necessary to vigorously promote the intensive cultivation technology of *O. europaea*.

**Key words** *Olea europaea*, Cultivation, Experiment

## 1 Introduction

The intensive cultivation technology of *Olea europaea* is a new cultivation and management technology commonly promoted in the place of origin of *O. europaea* overseas[1-4]. Using the appropriate intensive cultivars, and integrating the high-tech achievements and advanced management tools, can increase output per unit area, and greatly save manpower and land costs, so as to greatly improve the orchard output efficiency, therefore, this technology is commonly used in the newly-built olive orchard in the place of origin of *O. europaea*[5-7]. In recent years, various countries introducing the *O. europaea* varieties have begun to adopt the intensive cultivation technology, and new olive orchards are built in the flat and gentle land area in Mianning, Sichuan and Wudu, Gansu. Learning from the successful experience of foreign countries, to promote the use of this technology represents the development direction of China's *O. europaea* industry.

## 2 Materials and methods

**2.1 Overview of the experimental site** One experimental site is located in Dabao Village, Chengguan Town, Wudu District, Longnan City, Gansu Province. It is in the core of the first-level adaptive zone of Chinese *O. europaea*, and in the middle section of the olive-suitable area of Bailongjiang Valley in Longnan, Gansu. Geographical coordinates are 104°27′684″ E, 33°24′24.01″ N, and the altitude is 1 050 m. It is the transitional zone between northern subtropical zone and warm temperate zone, and the annual average temperature is 15.3℃. The extreme maximum temperature is 37.8℃, the extreme minimum temperature is -8.1℃, and the annual rainfall is 411.6 mm. The annual sunshine time is 2 104.4 h, and the annual frost-free period is 252 d. The soil is yellow brown slope soil, the sand content is 62%, and the soil is deep. The pH value is 7.8, neutral to slightly alkaline.

Another experimental site is located in Sishang Village, Shawan Town, Dangchang County, 70 km away from Dabao experimental site. The meteorological elements and site conditions are similar to those of Dabao. The *O. europaea* distribution zone of Bailongjiang Valley in Longnan, Gansu, belongs to Wen County, Wudu District and Dangchang County, respectively, in the lower, middle and upper section of Bailongjiang River in Longnan, and the weather factors, site conditions, topography and other ecological factors are similar.

**2.2 Experimental materials** The test materials are 712 *O. europaea* seedlings with nutritional bowl introduced from Spain in February 2011, a total of 8 varieties: "Koroneiki", "Arbequina", "Cornicabra", "Manzanillo", "Empeltre", "Hojiblanca", "Picual", "Arbosana". The domestic variety is "Ezhi 8".

**2.3 Experiment methods**

**2.3.1** Pre-planting treatment methods. After the seedlings were transported from Spain to Wudu, the basic data were taken and tested, followed by the numbering and filing plant by plant. After the seedlings were transplanted in the pots, and put in the labyrinth isolation room with three protection functions for 70 d isola-

Received: October 5, 2017 Accepted: January 8, 2018

Supported by the Central Finance Forestry Science and Technology Extension Project (2016ZYTG8).

* Corresponding author. E-mail: gslnzzw@163.com

tion and observation. The survival rate reached 99%, and most plants grew normally and produced flowers, showing initial adaptability. In May 2011, it was planted in Dabao *O. europaea* test orchard, Institute of Olive Research, Longnan Academy of Economic Forest Sciences.

**2.3.2** Planting methods. Two kinds of density planting were adopted. The first was the planting in the plots with flat surface, deep soil and fertile soil, for the purpose of adaptive observation. In order to speed up the growth of the trees and provide more propagation materials, the 3 m × 4 m density planting was adopted. The second was the high density cultivation to observe the high yield, and the plot density of the experimental site was 1.22 m × 3.65 m and 1.52 m × 3.96 m[6].

The excavation specifications were 712 huge planting holes (1 m × 1 m × 1 m). We bought 60 $m^3$ farmyard manure, 600 kg phosphate, 300 kg diammonium phosphate, and prepared 300 $m^3$ nutritional soil. The nutritional soil was put into the planting holes to reach 80 cm, the tree with soil was transferred from the container to the holes, erected, and the nutrient soil was added, so that the depth of trunk in soil was the same as in the container. By earthing up, the 0.3 m high 1 m × 1 m square tree tray was made. After pouring enough water to root, the tree tray was covered with one layer of dry soil for preservation of soil moisture. At both ends of trees and in many positions, 2.5 m high upright stick was used to firmly fix, and 3 galvanized iron wires were set in the position 0.9 m above the tree as the lattice support system. From the base of the trunk to the top of the tree, the knot was tied about every 0.5 m to fix the trunk to the lead wire or rod.

**2.3.3** Management methods. In 2013, the integrated water and fertilizer intelligent controllable water-saving irrigation system was constructed, and it was designed by the Greek Mediterranean Olive Research Institute, produced by Netafim Israel. During the first two years, in order to maintain maximization of reproductive materials, it was not trimmed. At the end of the third year, based on the needs of leader branch cutting and seedling cutting, all shoots and buds lower than 0.90 m were cut off. At the end of the third year and after the first harvest, all thick (diameter greater than 3/4 of the diameter of trunk) side branches were cut off; the long branches blocking the light on the lower branches and the adjacent row of trees were trimmed; in addition, some fruiting branches were cut off to ensure that the trees could get enough light.

The tree height was controlled to be 2.74 – 3.05 m (working height of fruit picking machine). Subsequently, the artificial pruning was conducted each year, to ensure that there were no side branches on the trunk with distance of 0.90 m from the ground. The side branches of more than three years were cut off, and the fruiting buds germinating directly from the trunk during the first two growing seasons were retained. Therefore, most of the fruits grew on the drooping branches, and the length of these branches was only 0.60 to 0.76 m.

**2.3.4** Analytical methods. By comparing different ways to build orchard, the yield of different varieties was tested and analyzed in 2010, 2012, 2013, respectively. After *O. europaea* came into maturity in 2010, the field investigation was conducted on more than 100 traditional close planting orchards and ordinary orchards of over-5-year-old *O. europaea* with fruit-bearing age in 18 towns of the main producing areas of *O. europaea* in Wen County, Wudu District and Dangchang County, respectively. In 2013, 10 intensive management demonstration samples and 10 ordinary cultivation samples were randomly selected from the intensive cultivation demonstration site of domestic variety "Ezhi 8" in Sishang Village, Shawan Town, Dangchang County, to conduct a comparative analysis of growth and yield. From the harvesting in 2014, the researchers Yu Ning and Deng Mingquan, from Professional Committee of Olive of Chinese Economic Forestry Association, were invited to test the yield of 1 + 4 a Spanish new *O. europaea* variety planted in Dabao test orchard, Institute of Olive Research, Longnan Academy of Economic Forest Sciences.

By comparing different ways to build orchards, the accounting analysis was performed on the orchard construction cost.

## 3 Results and analysis

### 3.1 Comparison of yield between the intensive cultivation and ordinary cultivation

**3.1.1** Comparison of yield between domestic traditional intensive cultivation and ordinary cultivation. In 2010, the on-site field investigation was conducted in the traditional close planting orchard and ordinary orchard of *O. europaea* (Table 1). From Table 1, it was found that the average yield in the close planting orchard was 13.5 kg/plant, the maximum yield was 40 kg/plant, and the average fresh fruit yield per unit area was 11 780 kg/ha. Based on the average fresh fruit purchase price of 9 yuan/kg, it was calculated that the fresh fruit output value reached 106 016 yuan/ha; based on the 9 processing enterprises' average industrial oil production rate of 13.64%, the oil production rate was calculated to be 1 607 kg/ha. The average yield of ordinary orchard was 6.8 kg/plant, the average fresh fruit yield per unit area was 3 915 kg/ha, the output value per unit area was 35 235 yuan/ha, and the oil production rate was 534 kg/ha.

By comparing the traditional close planting orchard and ordinary orchard, it was found that the average yield per plant and the output value per plant in the close planting orchard were twice as the average yield per plant and the output value per plant in the ordinary orchard, and the fresh fruit yield per unit area and the fresh fruit output value per unit area in the close planting orchard were thrice the fresh fruit yield per unit area and the fresh fruit output value per unit area in the ordinary orchard, indicating that the yield potential was great in the close olive planting orchard in the initial full bearing period, and the wide planting was conducted after 8 – 10 a to increase the pre-production.

**3.1.2** Comparison of "Ezhi 8" yield between intensive cultivation and ordinary cultivation. In 2013, the growth and yield comparison results of the domestic variety "Ezhi 8" sample under in-

tensive cultivation and ordinary cultivation can be shown in Table 2.

**Table 1 Comparison of fresh fruit yield and output value of Olea europaea between close planting orchard and ordinary orchard in Longnan, Gansu in 2010**

| Planting pattern | Density//plant/ha | Yield//kg/plant | Output value//kg/ha | Average output value per plant//yuan | Average output value per unit area//yuan/ha |
|---|---|---|---|---|---|
| High density orchard | 870 | 13.5 | 11 780 | 121.5 | 106 016 |
| Traditional orchard | 570 | 6.8 | 3 915 | 61.2 | 35 235 |

Note: The output value was calculated based on the average fresh fruit purchase price of 9 yuan/kg.

**Table 2 The growth and yield comparison between the high density orchard and the ordinary orchard in SiShang Village in 2013**

| Planting pattern | Cultivated varieties | Sample size | Average tree height//m | Average ground diameter//mm | Planting density | Average yield per plant//kg | Yield per unit area//kg/ha |
|---|---|---|---|---|---|---|---|
| Traditional orchard | Ezhi 8 | 10 | 3.457 | 74.20 | 4.0 m×5.0 m | 7.935 | 3 927.75 |
| High density orchard | Ezhi 8 | 10 | 2.903 | 65.69 | 1.5 m×3.5 m | 3.325 | 7 387.50 |

As can be seen from Table 2, for the same variety and the same test point, the average tree height of 6 a "Ezhi 8" in the early fruiting period was 3.457 m in the ordinary orchard, the average tree height of 6 a "Ezhi 8" in the early fruiting period was 2.903 m in the high density orchard, and the tree height growth in the ordinary orchard was 119% of the tree height growth in the high density orchard. The average ground diameter was 74.2 mm in the ordinary orchard, the average ground diameter was 65.69 mm in the high density orchard, and the ground diameter growth in the ordinary orchard was 112% of the ground diameter growth in the high density orchard.

The average yield per plant in the ordinary orchard was 7.935 kg, the average yield per plant in the high density orchard was 3.325 kg, and the average yield per plant in the ordinary orchard was 238% of the average yield per plant in the high density orchard. The yield per unit area in the ordinary orchard was 3 927.75 kg/ha, the yield per unit area in the high density orchard was 7 387.50 kg/ha, and the yield per unit area in the ordinary orchard was only 62% of the yield per unit area in the high density orchard. The planting density was low in the ordinary orchard, and the plant growth was large. The planting density was high in the high density orchard, and the plant growth was smaller than in the ordinary orchard. The high density orchard adopted the close planting measures, and the number of plants per unit area in the high density orchard was 8 to 10 times the number of plants per unit area in the ordinary orchard, and the yield per unit area in the high density orchard was much higher than in the ordinary orchard. "Ezhi 8" was not the most suitable intensive cultivar, and the ratio of the efficiency of ordinary orchard to the efficiency of close planting orchard per unit area was 1∶1.87.

**3.2 Yield comparison of new Spanish varieties under intensive cultivation** In 2014, the field test results of new Spanish varieties of *O. europaea* can be shown in Table 3.

**Table 3 The growth and yield comparison among the new Spanish olive varieties from Wudu Dabao new *Olea europaea* variety test orchard**

| Cultivation varieties | Sample size//plant | Tree age//a | Average tree height//cm | Average ground diameter//mm | Planting density | Average yield per plant//kg | Yield per unit area//kg/ha |
|---|---|---|---|---|---|---|---|
| Koroneiki | 10 | 1+4 | 306.80 | 61.54 | 3 m×4 m | 8.782 | 7 245.15 |
| Arbequina | 10 | 1+4 | 327.36 | 57.07 | 3 m×4 m | 9.295 | 7 668.45 |
| Cornicabra | 10 | 1+4 | 299.25 | 77.59 | 3 m×4 m | 4.119 | 3 398.25 |
| Manzanillo | 10 | 1+4 | 325.28 | 67.81 | 3 m×4 m | 2.632 | 2 171.40 |
| Empeltre | 10 | 1+4 | 423.91 | 71.89 | 3 m×4 m | 3.136 | 2 587.20 |
| Hojiblanca | 10 | 1+4 | 358.14 | 66.66 | 3 m×4 m | 3.529 | 2 911.50 |
| Picual | 10 | 1+4 | 339.57 | 80.10 | 3 m×4 m | 8.919 | 7 358.25 |
| Arbosana | 10 | 1+4 | 289.53 | 58.38 | 3 m×4 m | 6.430 | 5 230.50 |

It can be seen from Table 3 that the eight new *O. europaea* varieties introduced from Spain to Dabao, Wudu, Gansu, underwent sporadic fruiting in the third year, and the early fruiting appeared after four years of planting. For "Arbequina" with the highest yield, the average yield per plant reached 9.295 kg, and the yield reached 7 668.45 kg/ha. The yield of "Picual", "Koroneiki", "Arbosana" was higher than 5 250.00 kg/ha, reaching the standard of Wudu high-yielding planting orchard. It could be initially concluded that the four varieties had the characteristics of early fruiting and high yield in Wudu, Gansu. "Picual" is the main conventional variety cultivated in Spain, and due to large and robust tree, hard and brittle branches and extension of fruiting parts, it was not suitable for close planting. The other three varieties had the main characteristics of close planting, the tree erection was good, and the fruiting branches were mainly the 2-year-old branches germinating from the trunk. The germination capability of branches was strong, the branches were flexible, so as to facilitate the mechanized harvesting.

**3.3 Construction cost analysis of the high density orchard and ordinary orchard** The construction investment analysis re-

sults of the high density orchard and ordinary orchard can be seen in Table 4. As can be seen from Table 4, the land preparation requirement was not high in the ordinary orchard, and the principle of building the orchard following the topography was generally taken. The main workload of land preparation was to level the surface and dig planting holes. The high density orchard should take the whole site preparation, and the tillage depth was 1.2 m. The ridges and furrows were made flat to meet the operation needs of farming machinery, fruit picking machinery and transport machinery in the orchard. In general, the cost of land preparation in the high density orchard was 6.24 times the cost of land preparation in the ordinary orchard. There was a need to establish a fixed frame, and due to different materials, the frame cost was generally 22 500 to 75 000 yuan/ha. The application rate of fertilizers and pesticides also increased, because the number of olive trees planted in the high density orchard was 5 times the number of olive trees planted in the ordinary orchard.

At present, most of the ordinary olive orchards used the means of flood irrigation in the whole garden, and there was no difference between the ordinary orchard and the high density orchard. Only in the dry season, the water consumption was high in the high density orchard, and it was necessary to conduct additional irrigation or resist drought multiple times. If the supporting water and fertilizer integration system was constructed, 0.6 $m^2$ of water supply for each tree in Wudu, Gansu, could meet the needs of tree growth, greatly reducing the cost. However, the cost of designing a standard integrated water and fertilizer system was about 37 500 to 75 000 yuan /ha, and the reasonable control area was 33 – 330 ha for each integrated water and fertilizer system. The economic control area of Israeli medium-sized irrigation machine was 200 ha, and in accordance with the economic life of intensive *O. europaea* orchard at 25 years, after these costs were apportioned into the annual cost, it was not too high, and it is worth it. The high density orchard generally adopted the intensive cultivation technology, and the management cost was greatly reduced. On the whole, the construction cost ratio of the ordinary orchard to the high density orchard was 1∶6.24. Under the high water and fertilizer conditions, if using the intensive cultivars, the yield ratio of the ordinary orchard to the high density orchard was 1∶4.481, with significant benefit.

**Table 4 The comparison of investment in constructing high density orchard and ordinary orchard**

| Planting way | Planting density | Planting cost | | Compound fertilizer, microfertilizer, pesticide cost | | Irrigation cost | | Lattice cost yuan/ha | Management cost yuan/ha | Total yuan/ha |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Land preparation and planting cost // yuan/ha | Seeding cost yuan/ha | Application cost per plant // yuan | Application rate per hectare yuan/ha | Water consumption per plant // $m^3$ | Irrigation cost per hectare yuan/ha | | | |
| Traditional orchard | 4.0 m×5.0 m | 12 000 | 6 000 | 5.4 | 1 620 | 0.6 | 12×3 | – | 45×80 | 23 256 |
| High density orchard | 1.7 m×4.0 m | 67 000 | 29 400 | 5.4 | 7 938 | 0.6 | 60×3 | 37 500 | 10×80 | 145 318 |

## 4 Conclusions and discussions

As can be seen from the above analysis, it is found that the ultra-high density *O. europaea* orchard is the intensive *O. europaea* cultivation mode with the best benefit, having early maturity, high yield, high degree of mechanization, short payback period and many other advantages. However, the cost of planting system is high, so it is necessary to have perfect irrigation facilities, strict pest control measures, fine professional management, suitable variety selection, and convenient topographic and terrain conditions for mechanized harvesting.

(i) The terrain of intensive *O. europaea* orchard should be relatively flat, the slope must not be greater than 5°, and the area should be greater than 10 ha. It should be concentrated and contiguous, and the big gullies or ridges should be avoided. The intensive cultivation mainly adopts the mechanized operation, so it is not suitable in the mountains, thus restricting the use of this technology.

(ii) Before the new varieties were selected and bred, it is necessary to choose the following three varieties: "Arbequina", "Arbosana" and "Koroneiki". There is olive orchard in Longnan of Gansu using "Ezhi 8" to build a high density intensive orchard, but due to the features of high tree, unobvious trunk, stout side branches, few fruiting branches and open crown shape, it is not easy to conduct mechanized operation.

(iii) The dwarfing close planting cultivation technology is used, and the density is 741 – 1 902 plants/ha. The general planting density of close planting orchard is 2.44 m×4.88 m, and the general planting density of ultra-high density orchard is 1.5 m×3.5 m, thus taking full advantage of land and light and heat resources. The grid system was established to fix the main branch and control the growth angle of side branches. The too large branches were cut off in time to control the height of the tree. Sichuan Mianning has built largest high density demonstration orchard with the largest area and high standard in China. The construction time is short and the benefit has not been brought into full play. Observation and research need to be continued.

(iv) The row spacing is large while the plant spacing is small in the high density orchard and ultra-high density orchard. The light transmissibility and ventilation between the rows are ensured, and the full isolation of pests is ensured between rows. However, the distance between plants is very small, and the natural extension of branches causes the interweaving of trees, so the poor ventilation and poor light transmissibility have created conditions for the growth of pests and diseases. It is necessary to always monitor the pest and disease damage situation and grasp the trend of its occurrence while doing a good job pest and disease control in accordance with the operational calendar.

(v) Strictly according to the biological characteristics of *O. europaea*, as well as the characteristics of temporal and spatial distribution of rainfall, it is necessary to supply sufficient water for overwintering, ensure water for flowering, and timely replenish water, to

ensure robust growth and high yield of fruit.

(vi) According to the growth and development stages of the tree, it is necessary to conduct timely diagnosis of tree nutrition, and implement formula fertilization. According to soil nutrients and tree nutrition changes, there is a need for timely replenishment of N, P, K and other nutrients, and Ca, B, Mg, Zn and other trace elements.

(vii) It is necessary to establish the supporting integrated water and fertilizer system in the orchard, use the green pollution-free technology to control pests and diseases, and use the mechanical pruning and mechanical harvesting.

(viii) The intensive cultivation of *O. europaea* is to produce more *O. europaea* fruits at the stage with the strongest fruiting capacity through the technical measures, so that *O. europaea* can maintain strong production and fruiting capacity to achieve maximum benefits. Overseas, it is generally considered that the first 25 a is the period of the strongest production capacity, and after 25 a, the production capacity of the tree gradually declines. The orchard is rebuilt to update, and in the first 4 years when deciding to update the orchard, there is a need to choose the latest intensive cultivars, and cultivate the *O. europaea* seedlings under the high water and fertilizer conditions in the nurseries. After 4 a, the *O. europaea* seedlings have had considerable production capacity, and the update measure is to remove the old trees in the orchard, and plant the cultivated *O. europaea* seedlings directly in the updated orchard land, thus ensuring the continuous and efficient orchard production and maximizing the economic benefits.

The intensive *O. europaea* cultivation technology represents the development direction of the olive industry. In recent years, this technology has been introduced domestically and a number of demonstration orchards have been built in succession. However, due to the emphasis on the research of production and construction of orchard, the technical analysis, cost analysis and integrated management technique study are still in the initial stage[8-10]. This study is a preliminary summary of the domestic intensive test on *O. europaea*, and due to limited data collected and the insufficient observation time, the depth of analysis and research needs to be expanded. In the future, it is necessary to continue to observe and study the intensive *O. europaea* orchard having been built in Gansu Longnan and Sichuan Mianning, improve the orchard construction technology and management measures, promptly carry out the breeding of intensive cultivars, and introduce the foreign advanced production equipment and technology to make this technology more mature.

## References

[1] CHEN J, ZHANG DS, JIA ZK. Super - high - density olive orchard—An intensive planting model of olive in the world [J]. Hunan Forestry Science & Technology, 2009, 36(3): 28 - 30. (in Chinese).

[2] VOSSEN PM, CONNELL JH, KRUEGER H. Samples costs to establish a super - high - density olive orchard and produce oil in the Sacramento Valley [M]. California: University of California Cooperative Extension Division of Agriculture and Natural Resources Oakland, 2007: 23 - 25.

[3] WANG JW, ZHANG DS, LI YY, *et al.* Study on fertilizing and irrigating technique on olive critical growth period [J]. China Forest Products Industry, 2015(5): 31 - 35. (in Chinese).

[4] ZHANG ZW, ZHAO QH, DENG Y, *et al.* Inspiration of coordinated experience in olive production and research in Greece to the olive industry of China [J]. Northern Horticulture, 2012(15): 199 - 202. (in Chinese).

[5] VOSSEN PM. Olive oil: History, production, and characteristics of the world's classic oils [J]. Hortscience, 2007, 42(5):1093 - 1100.

[6] VOSSEN M. Super - high - density olive oil production [J]. Olint, 2002 (1): 17 - 23.

[7] ZHONG HY, LI J, TAN XF. Survey report on olive industry development situation in Australia and New Zealand [J]. Economic Forest Researches, 2012, 30(2): 144 - 146. (in Chinese).

[8] WEI SQ, WU Q, HUANG LZ, *et al.* Effects of biogas fermentation residue and compound fertilizer on growth and fruiting of *Camellia oleifera* [J]. Journal of Central South Forestry University, 2014, 34(3): 53 - 57. (in Chinese).

[9] HAN HB, LUO HP, LIAO MA, *et al.* A research progress review on water requirement in *Olea europaea*[J]. Journal of Central South Forestry University, 2011, 31(3): 85 - 89. (in Chinese).

[10] ZHANG HP. Experiment of cuttings rooting ability in new olive cultivars [J]. Economic Forest Researches, 2014, 32(3): 192 - 196. (in Chinese).

(From page 53)

## References

[1] RONG TZ. Maize breeding in the Southwest ecological area[M]. Beijing: China Agriculture Press,2003:26 - 27. (in Chinese).

[2] TUO HZ, YAO JX, CHENG FP, *et al.* Current situation analysis and development countermeasures of corn mechanized production in Sichuan mountainous and hilly areas [J]. Chinese Agricultural Mechanization, 2016,37(6):264 - 267. (in Chinese).

[3] WANG PY. The affect of agronomic traits by different depth of seeding and fertilization levels on the *Kengyilia thoroldiana* [D]. Xining: Qinghai University,2013. (in Chinese).

[4] WU HY, CUI YH, SUN CF. Study on relations of sowing depth and seedling emergence of different types of maize seeds[J]. Journal of Maize Sciences,2011,19(2):109 - 113. (in Chinese).

[5] MOLATUDI RL, MARIGA RK. The effect of maize seed size and depth of planting on seedling vigour[J]. Journal of Applied Science Research, 2009(5): 2234 - 2237.

[6] ZHU WH, TIE SG, SUN JJ, *et al.* Effect of different soil texture and depth of sowing seed on the seedling emergence potential of sweet corn hybrids[J]. Journal of Henan Agricultural Sciences,2005(11):35 - 36. (in Chinese).

[7] GAO YB, TAO HB, ZHU JC, *et al.* Effects of wheat stubble height on growth and water use efficiency of mechanized sowing summer maize[J]. Scientia Agricultura Sinica,2015,48(19):3803 - 3810. (in Chinese).

[8] OZMERZI A, KARAYEL D, TOPAKCI M. Effect of sowing depth on precision seeder uniformity[J]. Biosystems Engineering, 2002 , 82(2): 227 - 230.

[9] CAO HY, WANG DB, SHI JG. Effects of sowing depth on seedling traits and root characteristics of summer maize[J]. Chinese Journal of Applied Ecology,2015,26(8):2397 - 2404. (in Chinese).